JOURNAL OF ANIMAL SCIENCE
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J Anim Sci 2010.88:1771-1776.
doi: 10.2527/jas.2009-2325 originally published online Feb 12, 2010;

Effects of crude glycerin on performance and carcass characteristics of finishing wether lambs[1]

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ABSTRACT: The objective of this study was to evaluate the effects of crude glycerin on performance and carcass characteristics in finishing wether lambs. Thirty black-faced, Suffolk-cross wether lambs (44.1 ± 5.6 kg initial BW) were stratified and blocked by BW to 1 of 5 individually fed, isocaloric, isonitrogenous dietary treatments containing 0, 5, 10, 15, or 20% crude glycerin (88% pure) on a DM basis. Diets were fed once daily for ad libitum consumption and contained 15% chopped hay, approximately 25% dried distillers grains with solubles, and the specified treatment combination of cracked corn replaced with increasing amounts of crude glycerin. Wethers were weighed on 14-d intervals and were selected for slaughter when they reached an approximate 12th-rib fat depth of 0.51 cm (28 to 84 d on trial). Carcass characteristics were collected after a 48-h chill. Dry matter intake (linear, $P = 0.004$) and ADG (quadratic, $P = 0.05$) increased with increasing concentrations of glycerin in the diet during the first 14 d of the feeding period. Similarly, G:F tended to increase quadratically ($P = 0.06$) with increasing concentrations of crude glycerin in the diet during the first 14 d. However, there were no differences among treatments for final BW, days on feed, or cumulative DMI, cumulative ADG, and cumulative G:F ($P \geq 0.11$). Body wall thickness, dressing percent, HCW, LM area, flank streaking, leg score, conformation score, quality grade, yield grade, and percent boneless, closely trimmed retail cuts did not differ ($P \geq 0.21$). Adding up to 15% crude glycerin to finishing wether diets improved feedlot performance, particularly during the first 14 d, without any concomitant effect on carcass characteristics.

Key words: dried distillers grains with solubles, glycerin, lamb, wether

J. Anim. Sci. 2010. 88:1771–1776
doi:10.2527/jas.2009-2325

INTRODUCTION

Recent growth in the biofuel industries has resulted in volatile futures markets and increased grain costs traditionally used in feedlot diets. To sustain profitability and thrive within their respective industries, livestock producers from all sectors are seeking ways to reduce production costs. Because feed is the largest cost in any production system, using economical, alternative feedstuffs may be one avenue to maintain or increase profitability. In the Eastern Corn Belt, where ethanol and biodiesel plants are found in greatest density, by-product feeds, including dried distillers grains with solubles (**DDGS**) and crude glycerin, are alternative feedstuffs that are rich in CP and energy, respectively, and can be less costly than traditional CP and energy sources such as soybean meal and corn.

Increased crude glycerin availability resulting from the surge in biodiesel production may result in a reduced-cost feed energy source when compared with traditional sources. Additionally, glycerin has the potential to partially replace starch-based ingredients in the diet, such as corn, because glycerol (an 85% constituent of crude glycerin) is converted to propionate in the rumen and acts as a precursor for hepatic glucose synthesis (Johns, 1953). Although recent studies have included crude glycerin in beef feedlot diets (Pyatt et al., 2007; Versemann et al., 2008; Parsons et al., 2009), its effects on animal performance and carcass characteristics have not been well defined. In finishing lambs, Musselman et al. (2008) assessed the effects of feeding glycerin at 0, 15, 30, and 45% of dietary DM on performance and carcass variables. However, to our knowledge, there is little, if any, literature on feeding finishing lambs glycerin at less than 15% of dietary DM. Therefore, the objective of this study was to evaluate the effects of feeding crude glycerin at 0 to 20% of dietary DM on

[1]Appreciation is extended to Integrity Biofuels (Morristown, IN) for providing soybean-based crude glycerin for this project, as well as to the employees of the Purdue University Sheep Research and Teaching Center (West Lafayette, IN) for help in conducting the research.
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Received July 21, 2009.
Accepted January 15, 2010.

Table 1. Diet formulation and analyzed nutrient content of experimental diets containing 0, 5, 10, 15, and 20% crude glycerin fed to finishing wether lambs

	Crude glycerin, % of dietary DM				
Item	0	5	10	15	20
Ingredient, % of dietary DM					
Dry-rolled corn	39.9	30.4	24.9	15.2	18.6
Dried distillers grains[1]	25.0	25.0	24.4	26.0	24.6
Soybean hulls	16.3	19.9	19.8	23.3	14.0
Ground alfalfa-grass mixed hay	14.9	14.9	14.8	14.9	14.6
Soybean meal	—	0.8	2.0	1.8	4.2
Crude glycerin	—	5.1	10.2	14.8	20.1
Liquid molasses	1.1	1.1	1.1	1.1	1.1
Mineral-vitamin premix[2]	2.06	2.06	2.06	2.06	2.06
Ammonium chloride	0.37	0.37	0.37	0.37	0.37
Thiamine-10[3]	0.30	0.30	0.30	0.30	0.30
Mold inhibitor	0.07	0.07	0.07	0.07	0.07
Analyzed nutrient composition,[4] % of DM					
CP	15.0	15.0	14.9	15.1	15.3
NDF	23.4	24.1	24.5	23.8	24.8
Ca	1.03	1.00	1.01	0.99	1.08
P	0.43	0.41	0.42	0.40	0.43
NE_g, Mcal/kg	1.25	1.28	1.25	1.25	1.25
DM	83.6	84.8	85.5	82.9	82.5

[1]Dried distillers grains contained (DM basis): 29.5% CP, 12.7% fat, 14.3% ADF, 0.88% P, 0.05% Ca, 1.08% K, 0.27% Mg, 0.81% S, 0.26% Na, and 1.18 Mcal/kg of NE_g.

[2]Hunter's Lamb 55 B Premix (Hunter Nutrition Inc., Brookston, IN) contained: 28.8% Ca, 17.91% salt, and 0.67% fat as well as 534,600 IU of vitamin A, 157,300 IU of vitamin D, and 2,350 IU of vitamin E per kg of premix.

[3]Diet formulated to contain 30 mg/kg of thiamine (Akey Nutrition, Lewisburg, OH).

[4]Based on analysis of composite feed samples.

feedlot performance and carcass characteristics of finishing wether lambs.

MATERIALS AND METHODS

All procedures involving animals during the study were approved by the Purdue Animal Care and Use Committee before the initiation of research.

Animals and Diets

Before initiation of the study, all wethers were fed a common 14% CP grower diet consisting primarily of corn and alfalfa haylage. To evaluate the effects of feeding varying concentrations of crude glycerin during the finishing phase, 30 shorn, black-faced, Suffolk-cross wether lambs (44.1 ± 5.6 kg) were stratified and blocked by BW in a randomized complete block design. Wethers were randomly assigned within block to 1 of 5 treatments (6 lambs/treatment), and were individually fed and housed in a curtain-sided, mesh-floored finishing barn.

The 5 corn-based dietary treatments (Table 1) consisted of 0, 5, 10, 15, or 20% crude glycerin (DM basis) and were formulated to be isonitrogenous and isocaloric (on a NE_g basis) and to meet or exceed the NRC (2007) requirements of a finishing lamb. Musselman et al. (2008) noted linear decreases in feedlot performance and carcass characteristics of lambs when fed 15, 30, and 45% crude glycerin; however, no differences were noted between 0 and 15% crude glycerin supplementation. To further evaluate the optimal amount of glycerol in the diet of finishing lambs, the current study was designed to assess the effects of feeding crude glycerin below 20% of the ration DM. Additionally, recent research has demonstrated that DDGS do not affect performance or carcass characteristics of finishing lambs when included at amounts as great as 50% (Van Emon et al., 2008) and 60% (Schauer et al., 2008) of dietary DM. Based on these data, we were confident that use of DDGS as the primary CP source would not confound the current study; therefore, diets were formulated to meet CP requirements using DDGS at approximately 25% of dietary DM.

Crude glycerin was acquired from a soybean oil-based biodiesel production facility (Integrity Biofuels, Morristown, IN). The analysis of crude glycerin was performed by the University of Missouri–Columbia Experiment Station Chemical Laboratories. Results of the analysis and methods used are listed in Table 2. Briefly, moisture (method 984.20, AOAC, 1995), methanol (gas chromatography), ash (method 942.05, AOAC, 1995), salt (methods 956.01, 9.15.01, and 943.01, AOAC, 1995), S (method 956.01, AOAC, 1995), FFA (method Ca 5a-40, AOCS, 2000), and CP (method 990.03, AOAC, 1995) were analyzed. Based on these measurements, percentage of pure glycerin was determined by

Table 2. Characterization of soybean-derived crude glycerin[1,2]

Item	Value, %	Analytical method
Pure glycerin	87.50	Determined by difference[3]
Moisture	8.26	AOAC[4] method 984.20
DM	91.74	Determined by difference
Methanol[5]	0.009	Gas chromatography
Ash[5]	3.63	AOAC method 942.05
Salt[5]	3.57	AOAC methods 956.01, 9.15.01, 943.01
S[5]	<0.10	AOAC method 956.01
FFA[5]	<0.005	AOCS[6] method Ca 5a-40
CP[5]	0.50	AOAC method 990.03

[1]Crude glycerin was obtained from Integrity Biofuels (Morristown, IN).
[2]Analysis by University of Missouri–Columbia Experiment Station Chemical Laboratories.
[3]Determined as 100 − percentage of (methanol + ash + sulfur + FFA + CP).
[4]AOAC (1995).
[5]Expressed as a percentage of crude glycerin DM.
[6]AOCS (2000).

taking 100 − percentage of (methanol + ash + S + FFA + CP).

Feed was offered for ad libitum consumption once daily at 0800 h with free access to water. Feed refusals were weighed, analyzed for DM, recorded, and discarded to calculate DMI accurately. Individual feed ingredients were analyzed weekly for DM to adjust the diet composition for ingredient moisture content. Composite feed samples were collected weekly and dried in a forced-air oven at 60°C for 48 h for analysis of DM. Dried samples were ground to pass a 1-mm screen (model WRB 90LB/4P, Dietz-Motoren GmbH and Co., Dettingen, Germany) and analyzed for ether extract, ash (AOAC, 1990), and NDF and ADF (Ankom Technology, Fairport, NY). Nitrogen was determined by combustion (Leco Instruments Inc., St. Joseph, MI; method 976.06, AOAC, 1990) and multiplied by 6.25 to obtain CP.

Performance and Carcass Data

Initial BW of wethers was determined by averaging individual preprandial BW on d −1 and 0. Throughout the study, individual BW and 12th-rib subcutaneous fat depths were assessed and recorded on 14-d intervals to track performance and aid in slaughter selection. To determine the effects of crude glycerin inclusion on carcass quality, individual lambs were identified for slaughter when 12th-rib subcutaneous fat depths reached approximately 0.51 cm, as determined by trained personnel by way of palpation and visual evaluation. Final BW for each wether was determined using the average prefeeding BW from 2 consecutive days before slaughter. All lambs were slaughtered at the Purdue University Meat Science Research and Education Center (West Lafayette, IN). Hot carcass weights were recorded immediately after evisceration, whereas 12th-rib subcutaneous fat depth, body wall thickness, LM area, flank streaking scores, conformation scores, and quality grades were collected by trained personnel after a 48-h chill, using procedures described by Boggs et al. (2006). Final yield grades and percentage of boneless, closely trimmed retail cuts were calculated using formulas provided by Boggs et al. (2006), with auxiliary conversions used for metric units.

Statistical Analysis

All data were analyzed using SAS (Cary, NC) software. The MIXED procedure was used to analyze the fixed effects of treatment and block on performance and carcass characteristics, with animal serving as the experimental unit. Orthogonal contrasts were used to determine linear and quadratic effects, as well as the effect of the 0% glycerin diet vs. the average of all diets containing glycerin. Treatment means were computed with the LSMEANS option. Contrasts were considered significant when the P-value was ≤ 0.05, with a P-value of ≤ 0.10 considered as a tendency approaching significance.

RESULTS AND DISCUSSION

Performance

The number of days on feed required for wethers to reach a common 12th-rib fat depth ($P \geq 0.67$) and final BW ($P \geq 0.31$; Table 3) were not affected by dietary treatment. It should be noted, however, that lambs fed the 15% glycerin diet required 12.2% fewer days to reach their endpoint than did lambs fed 0, 10, and 20% glycerin.

When compared with lambs not fed glycerin, DMI of lambs fed 5, 10, 15, and 20% crude glycerin during the first 14 d increased linearly ($P = 0.004$) by 0.18, 0.21, 0.24, and 0.40 kg/d, respectively. Conversely, although a numeric increase in DMI was maintained to slaughter for lambs fed 10, 15, and 20% glycerin, cumulative DMI attributable to dietary treatment did not differ ($P \geq 0.11$). Data reported by Musselman et al. (2008) also reported no differences in DMI of finishing lambs fed up to 15% glycerin. In contrast, Pyatt et al. (2007) reported a decrease in DMI when diets containing 10%

Table 3. Effects of 0, 5, 10, 15, and 20% dietary crude glycerin on performance of finishing wethers

	Dietary crude glycerin, %						Contrast *P*-value		
Item	0	5	10	15	20	SEM[1]	Linear	Quadratic	0 vs. glycerin[2]
No. of wethers	6	6	6	6	6	—	—	—	—
Days on feed	54	68	53	48	57	9	0.67	0.97	0.80
BW, kg									
Initial	44.2	44.0	44.2	44.1	44.2	2.4	1.00	0.97	0.97
Final	56.2	57.6	58.1	57.5	57.1	1.2	0.65	0.31	0.31
DMI, kg/d									
d 0 to 14	1.01	1.19	1.32	1.36	1.41	0.10	0.004	0.34	0.01
Cumulative	1.43	1.41	1.59	1.57	1.55	0.074	0.11	0.49	0.26
ADG, kg									
d 0 to 14	0.10	0.24	0.24	0.40	0.24	0.060	0.03	0.05	0.01
Cumulative	0.23	0.20	0.28	0.29	0.23	0.029	0.28	0.25	0.50
G:F, kg/kg									
d 0 to 14	0.099	0.202	0.182	0.294	0.170	0.052	0.06	0.06	0.02
Cumulative	0.161	0.141	0.176	0.185	0.148	0.015	0.65	0.25	0.87

[1]n = 6.
[2]Effect of 0% dietary inclusion of crude glycerin vs. all diets containing crude glycerin.

crude glycerin were fed to finishing feedlot steers. Likewise, Parsons et al. (2009) reported a linear decrease in DMI when crude glycerin was included at more than 2% DM in finishing heifer diets. It has been hypothesized that increased concentrations of glycerin in the diet may lead to an unhealthy rumen, resulting in decreased overall DMI. Roger et al. (1992) demonstrated that introducing glycerol to the rumen environment reduced cellulolytic activity of rumen bacteria, and Paggi et al. (2004) reported that digestibility of other substrates in the diet might be inhibited with the inclusion of glycerol in an in vitro environment. However, more recent digestibility data support results from the current study. Krehbiel (2008) reported that microorganisms adapted rapidly to glycerol feeding because elevated disappearance rates of glycerol were noted with increased days of glycerol feeding. Additionally, Hess et al. (2008) reported that crude glycerin could be added at 15% DM to ruminant diets without negatively affecting DM or fiber digestibility. These data, coupled with data from the current study, suggest that the rumen environment, and concurrent decrease in DMI, may not be affected until crude glycerin concentrations exceed 15% of dietary DM. Further research, however, is needed to test this hypothesis and pinpoint the exact causes of decreased feedlot performance associated with elevated amounts (>15%) of crude glycerin in the diet.

Wethers fed 0, 5, 10, 15, and 20% crude glycerin had ADG during the first 14 d of 0.10, 0.24, 0.24, 0.40, and 0.24 kg, respectively (quadratic, $P = 0.05$). These increases in ADG at up to 15% inclusion of glycerin were most likely due to the increases in DMI during the first 14 d. Conversely, the depression in ADG of lambs fed 20% glycerin may be attributed to an altered ruminant environment, possibly resulting in reduced digestibility of other feedstuffs, as discussed previously. Although an increase in ADG was seen for all glycerin-fed lambs, compared with non-glycerin-fed lambs, during the first 14 d, cumulative ADG did not differ ($P \geq 0.25$). It should be noted, however, that overall ADG increased by 21.7 and 26.1% for lambs fed 10 and 15% glycerin, respectively, when compared with lambs not fed glycerin. Pyatt et al. (2007), Versemann et al. (2008), and Parsons et al. (2009) also demonstrated increased ADG in finishing cattle fed crude glycerin at up to 10% of dietary DM. However, in all those studies, a decrease in ADG was noted with cattle when glycerin exceeded 10% of dietary DM. Similarly, Musselman et al. (2008) reported a linear decrease in ADG of finishing lambs fed 0, 15, 30, and 45% glycerin.

Feed efficiency during the first 14 d of the study was greater for all glycerin-fed lambs when compared with lambs not fed glycerin ($P = 0.02$). There tended to be a quadratic ($P = 0.06$) response in G:F for wethers fed 0, 5, 10, 15, and 20% crude glycerin. Cumulative G:F, however, did not differ among treatments ($P \geq 0.25$). Lambs fed 5 and 20% glycerin experienced decreased cumulative G:F of 11.9 and 5.6%, respectively, when compared with lambs not fed glycerin. Pyatt et al. (2007) and Parsons et al. (2009) also reported increased feed efficiency in finishing beef cattle fed up to 10 and 12% crude glycerin, respectively. In addition, Parsons et al. (2009) and Musselman et al. (2008) demonstrated that feeding crude glycerin to finishing ruminants above 15% of DM decreased feed efficiency through decreased ADG, which also parallels results of the current study.

Data from the current study demonstrate that feeding crude glycerin up to 20% of dietary DM during the first 14 d of a dietary transition period may have a positive impact on lamb feedlot performance. Cumulative data, although not significant, imply that performance is optimized when crude glycerin is included in the diets of finishing weather lambs at 10 to 15% of DM. More specifically, lambs fed 10 to 15% crude glycerin had increases in ADG and G:F of 29.5 and 21%, respectively, while requiring 15.2% fewer days to reach their endpoint when compared with their contemporaries fed

Table 4. Effects of 0, 5, 10, 15, and 20% dietary crude glycerin on slaughtered carcass characteristics of finishing wethers

	Dietary crude glycerin, %						Contrast P-value		
Item	0	5	10	15	20	SEM[1]	Linear	Quadratic	0 vs. glycerin[2]
HCW, kg	32.7	34.9	33.7	32.4	34.3	0.75	0.81	0.81	0.21
Dressing percent	58.3	60.7	58.0	55.8	60.1	1.1	0.71	0.32	0.76
12th-rib fat thickness, cm	0.51	0.51	0.55	0.52	0.53	0.028	0.24	0.66	0.28
Body wall thickness, cm	2.78	2.75	2.77	2.59	2.87	0.14	0.94	0.44	0.86
LM area, cm^2	17.84	19.62	17.74	17.53	18.22	0.61	0.49	0.83	0.53
Flank streaking[3]	550	633	533	567	583	38	1.00	1.00	0.51
Conformation score[4]	12.5	12.7	12.8	12.7	12.7	0.60	0.86	0.76	0.75
Quality grade[4]	12.5	13.7	13.2	12.7	13.0	0.55	1.00	0.42	0.32
Yield grade[5]	2.40	2.40	2.58	2.45	2.48	0.11	0.24	0.66	0.28
%BCTRC[6]	45.95	46.20	45.61	46.07	45.57	0.32	0.36	0.56	0.87

[1]n = 6.

[2]Effect of 0% dietary inclusion of crude glycerin vs. all diets containing crude glycerin.

[3]Flank streaking: 500 to 599 = Modest; 600 to 699 = Moderate; 700 to 799 = Slightly abundant.

[4]Conformation score and quality grade: 1 = cull to 15 = Prime$^+$.

[5]Yield grade = 0.4 + (10 × 0.393 × 12th-rib fat thickness, cm).

[6]Percentage of boneless, closely trimmed retail cuts (%BCTRC) = [49.936 − (0.0848 × 2.204 × HCW, kg) − (4.376 × 0.393 × 12th-rib fat thickness, cm) − (3.52 × 0.393 × body wall thickness, cm) + (2.456 × 0.155 × LM area, cm^2)].

0, 5, and 20% crude glycerin. It should be noted however, that these data are representative of lambs fed to a common fat depth endpoint. Therefore, lambs fed for a common number of days may experience no differences in performance because of dietary inclusion of glycerin up to 20% of DM. It is also of merit to note that clear trends in cumulative live performance data may not have been achieved because of the possible limitations associated with the number of experimental units.

Carcass Characteristics

By design, there were no differences in 12th-rib fat depth (Table 4) because lambs were slaughtered to minimize differences in backfat. Likewise, because preliminary yield grade is a function of only 12th-rib fat thickness, no differences attributable to dietary treatment were detected in yield grade. Additionally, no differences were attributable to dietary treatment for HCW, dressing percent, body wall thickness, LM area, flank streaking, conformation score, quality grade, or percentage of boneless, closely trimmed retail cuts. Because glycerin is rapidly converted to propionate (Johns, 1953) and because the acetate:propionate ratio is likely decreased in lambs fed crude glycerin, it is plausible that glycerin may have effects on body fat depots other than that associated with 12th-rib subcutaneous fat depth and body wall thickness, as measured in this study. Because of the scope of the current study, however, neither mesenteric fat measurements nor chemical composition of meat was determined. Additional research is therefore justified to elucidate the full effects of dietary glycerin on the various fat depots in ruminants.

Expansion of the biodiesel industry is likely to result in an increased availability of crude glycerin to be used as an economical energy source in feedlot diets. Data from this study illustrate that wethers fed finishing diets containing 15% crude glycerin (DM basis) may obtain improved feedlot performance parameters, particularly during a transition period associated with the first 14 d of the feeding period. Carcass characteristics, however, may not be affected with dietary crude glycerin inclusion rates of up to 20% of DM. Therefore, it is paramount that producers consider not only input costs and cost of BW gain, but also live animal and carcass pricing schemes when evaluating which amount of dietary crude glycerin might be most appropriate in an individual feedlot operation.

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